GEO-TECHNICAL INVESTIGATIONS FOR FOUNDATION DESIGN

MOLOTE VILLAGE

BOONS- NORTH WEST

FINAL REPORT

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EXECUTIVE SUMMARY

Mr Gregory Zulu of GMBC appointed Mshandukani Geotechnical Consultants to conduct a Geotechnical Investigation for foundation design of the proposed resort, chalets, administration block,cultural village &multi-purpose centre to be built at Molote Village, Boons, North West.

According to the published information, the most extensive area site is underlain by sandstone, dolerite, norite and shale of the Ecca Group of the Karoo Supergroup. The site is suitable for the proposed development providing that cognizance is taken of the foundation recommendations contained herein.

Soft excavation conditions (as per SANS 1200 D) generally prevail on site. Excavation of material was achieved using a TLB.

No groundwater seepage from perched water tables or local phreatic surfaces was recorded in all test pits. The local water table may therefore be expected at greater than 5m in depth. It must be noted that the test pits were excavated during wet season.

The material on site (Silty sand & silty clay) cannot be used as layer works material during construction. This material can be classified as G10 on TRH 14 of Material Classification. The soil on site is classified as **R, H1- H2** according to NHBRC soil classification where maximum of 7.5 - 30mm shrinkage is expected. The top layer of brown colluvium soil should be excavated. All foundation should be founded at average depth not below 1.6 m on medium hard rock **Dolerite, Norite or Shale.**

Laboratory results indicate that the material of the norite has a Bulk density of 1673 kg/m3 and optimum moisture content of 14.3 %. Material has a maximum CBR value of 2.4%; grading analysis shows that material can be classified as inorganic silts.

Normal Reinforced Strip Footing foundation is therefore recommended that In-situ reconstruction or ripping be done at an average depth of 1.6-2.0 m below surface on consolidated soil or rock. Proper compaction should be adhered to while back filling the trenches and foundations with G5 material and should be compacted to 95% MODAASHTO at 150mm interval.

Due to the high content of clay on site and very low soaked CBR, the designer may also opt to use **Raft foundation** so as to avoid disturbing the clay thereby minimizing the chances of swelling or settling. In-situ reconstruction or ripping is to be done at an average depth of 0.5m.

Road Recommendations: The reasonable assumption for future traffic is: Low-order mixed pedestrian and vehicle route, with a total traffic loading of <0.3 x 106 E80s per lane. (TRH4)

The following recommendations were made:

- In-situ reconstruction or ripping and compacting G9 Material sub-grade to 90% MOD AASHTO density.
- 150mm G2 Base compacted to 88% MOD AASHTO density.
- 300mm G5 sub-base compacted to 95% MOD AASHTO density.
- 40 mm Asphalt overlay with a double seal surface.

The comments and recommendations contained within this report are based on a limited number of test pits. It is therefore recommended that all excavation and foundation trenches be inspected by a geotechnical engineer or engineering geologist during construction to verify that the founding condition are not at variance with those described herein.

INTRODUCTION

Mr Gregory Zulu of GMBC appointed Mshandukani Geotechnical consultants, to conduct a geotechnical investigation for foundation design of the proposed resort, chalets, administration block, cultural village & multi-purpose center to be built at Molote Village, Boons, North West. The investigation was aimed at assessing materials properties and condition of existing foundations and establishes the specific site geotechnical condition and recommendation.

By default, the following forms part of geotechnical investigations:

- Specific Geology of the Site.
- Potential Geotechnical Restraining Factors.
- Excavation Conditions.
- Presence of Groundwater.
- Classification of the Site Material According To the TRH14 Classification System.

A 1:250 000 geological map of the area was studied prior to the investigation taking place.

2. The site

The investigated site is LOCATED AT MOLOTE VILLAGE, BOONS, NORTH WEST Province. No man-made drainage path observed to traverse the site.

3. Method of investigation

The field investigation comprised site visit and the excavation of 13 test pits in areas reflecting different soil horizons. All sites were profiled along the vertical excavation face by the author using the MCCSSO soil profiling technique advocated by Jennings, 1963 (see Appendix A). The rock faces were profiled according to current methods and procedures, (Brink ABA and Bruin RMH). Representative samples were submitted for testing to a commercial soils laboratory for the determination of the Foundation indicator tests.

4. Regional Geology

According to the published 1:250 000 geological map, the site is underlain by sandstone, dolerite, norite and shale of the Ecca Group of the Karoo Supergroup.

4.2. Soil Profiles

4.2.1 Colluvium

Colluvium was encountered in all test pits to depths up to 0.5m. This horizon for most test pits was described as Dry, dark brown, firm to stiff, intact, sandy silty clay, colluvium with grass roots. Where sufficiently thick, this horizon may be prone to settlement under loading and or wetting.

Other test pits have the following description: Dry, reddish brown, medium dense, silty sand, colluvium with grass roots.

4.2.2 Residual Dolerite, Norite & Shale.

Residual Dolerite & Shale was also encountered in most test pits at a maximum depth of 1.6m, with the following description: Dry to slightly moist, yellowish brown, firm to stiff, slicken-sided, silty clay, Residual dolerite and residual shale with boulders of dolerite. The presence of the slicken-sides is indicative of the potential expansiveness of the founding material.

4.2.3 Dolerite, Norite & Shale.

A light brown, moderately weathered, fine-grained, medium hard rock-hard rock, is found in TP1, TP 5, TP 10.

5. Site location and description

5.1 Geographic Description

Site is situated in Boons, North West.

5.2 Coordinates and Elevation

The site coordinates are 26°03'07.06"S 27°14'18.30"E with an elevation range of approximately 1650 meters above mean sea level.

5.3 Vegetation

The area is brown field area with existing structures surrounded by grass and shrub.

5.4 Climate

The area falls at De Martonne's aridity index of between 10 and 20. According to the Thornthwaite's moisture index, the area falls in the region of -20 to 0. This interprets to sub-humid condition. The Weinert's N value for this site is between 2 and 3. This simply means chemical weathering processes heavily predominates over mechanical weathering.

5.5 Drainage Patterns

Sheet wash, streams coupled with some erosion channels and man-made storm water drainage channel are the most predominant drainage patterns on site. The site drains in different directions depending on location on site.

1:50 and 1:100 Year Flood Lines

A 1:50 year flood line implies that an area below that line has a high probability of being flooded at least once in every fifty year period. Similar contextual definition applies for the 1:100 year flood line.

By law, residential developments below the 1:50 year flood lines areas are prohibited. This is due to the risk of flooding leading to property damage, health and life hazards, inconveniences etc.

A hydrological study should be commissioned to determine the 1 in 50 year flood line. Proper flood line should be available from the Local Municipality Town Planning Department.

5.6 Past Land Use

This land was previously used as a residential area.

5.7 Current Land Use

The land is currently used as a grazing land in the village.

5.8 Mining Activities

No Mining activities were identified on the area.

5.9 Condition of Existing Structures

Most of the existing structures observed on site showed no signs of structural distress that might be linked to founding conditions and poor brick work. The differential settlement in this area can occur as a result of poor drainage system where water percolates underneath foundation and washes away the unconsolidated fill material.

6. GEOHAZARDS

6.1 Seismic Hazard / Activities

Seismic-hazard can be described as being the physical effects of an earthquake or earth tremor. Examples of such phenomenon include surface faulting, ground shaking and liquefaction (Kijko A et al, 2004).

According to the published (Council for Geosciences) Seismic Hazard Identification Maps of South Africa, Site falls under an area with a 10 % probability of 0.12g (peak ground acceleration) being exceeded in a 50 year period.

The peak ground acceleration is the maximum acceleration of the ground shaking during an earthquake.

For masonry and concrete structures, a 4 to 5 Hz Spectral Acceleration is assumed. This natural frequency of the structure can give an indication of the spectral part of the earthquake motion time history that has the capacity to introduce energy into the structure. Spectral Acceleration (ARS – acceleration-response spectra) is the movement experienced by the structure during an earthquake / seismic event.

This phenomenon is known as resonance. Resonance is where the frequency of the applied harmonic force is consistent with the natural frequency of a vibrating body. At resonance, the vibrating body will exhibit the maximum amplitude of response displacement leading to extremely high structural distress similar to popular example of the Tacoma Narrows Bridge that was situated in Washington State, near Puget Sound. Therefore, frequencies far away - either lower or higher - from the natural frequency of the structure have little capability of damaging the structure.

This area is a low seismic hazard area and the construction materials to be used (gravel) are in harmony with the naturally occurring site conditions. As a result, no major problems are foreseen in this regard.

6.2 Ground Subsidence

Subsidence occurs in areas with large underground cavities typically resulting from large scale shallow to very shallow mining and also from dolomite/limestone dissolution. It can also appear where high thickness of unconsolidated material exists.

This site showed no signs of previous subsidence occurrences. Furthermore, there is no evidence or record of active mining in the immediate vicinities that might cause drop in the ground water level thus triggering ground subsidence. The site is a not a dolomitic land, so it cannot be subject to doline formation.

6.3 Sinkhole Formation

Similar to subsidence, sinkhole formation happens in areas with very large to extremely large underground cavities resulting from mining poorly designed shallow underground activities. Coal Mines in Mpumalanga Province and Gold Mines in Limpopo Province are typical examples of such. Dissolution of dolomites or limestones over millions of years also lead to cavity formations that might later manifest into sinkhole formation as evidenced very much so in Limpopo Provinces.

According to the research done, there are no records of wide shallow underground mining activities directly below this site.

There is no dolomite or limestone underlying the site so the chances of dolomite related sinkhole formation are unlikely.

6.4 Landslides and Mudslides

The probability of landslides and mudslides occurring at this area are rare. This is primarily due to the low climatic conditions and composition of residual and transported materials in this area.

7. HYDROGEOLOGY

7.1 General

Aeolian and alluvial sands are relatively fairly porous making it easier for infiltration to occur. Contact zones of different geological units, fractures, joints, faults are also preferred groundwater pathways. Other pathways include in situ features such as permeable pores and cavities within the strata. Groundwater occurrence in the project area is geologically and geo-structurally controlled.

7.2 Hydrogeology of Site

The topographical setting of the site discourages stagnation of water, following precipitation. Perched water table resulting from the contact between various geologic zones may occur during rainy seasons. This investigation was carried out in dry season.

By the time of investigation, excavations were dry to slightly moist.

The sidewalls of the borrow pits were stable with minor signs or cases of instability being noted during the investigation exposure window. All test pits were lightly backfilled with the in situ material immediately after profiling.

8. Geotechnical Evaluation

8.1 Construction Material Suitability

The aim of this geotechnical site investigation report was to determine the different engineering geological properties of the surface and subsurface soils in accordance with the GFSH–2 guidelines, NHBRC. The intention is to be able to recommend for the foundation designs for proposed resort, chalets, administration block, cultural village & multi-purpose centre to be built at Molote Village, Boons, North West.

The investigation shows that the structures can be founded on **Normal Strip Footing or Raft foundation.** According to NHBRC soil classification material is classified as **R,H1- H2** which allows differential settlement of 7.5 - 30mm.

Based on field assessment, Ground condition is suitable for **Normal Reinforced Strip Footing Foundation** and can be easily excavated to average depth of 1.6 m to 2m to remove top soil or overburden (silty clay) or **Raft foundation** to an average depth of 0.5m. All backfills should be with G5 material and to be compacted to 95% MODAASHTO.

Soil bearing capacity of soil is calculated at 30 kPa at refusal on highly weathered rock, Dolerite or Norite which is considered very weak because the safe bearing capacity of silty clay is 200kPa (Bangladesh National Building Code, 2012).

The results also indicate poorly graded sand with medium plasticity index, medium to high liquid limit and medium to high overall PI. That is because material on site has high clay content, medium to high Silt content, low to medium Sand content but low percentage ratio of gravels. Material on site According to unified classification system is classified as MH; MH, which is inorganic silts & inorganic clays of low to medium plasticity (silty clay) on colluvium with a matrix of Dolerite or Shale. Material has bulk density of 1673 kg/m3 with optimum moisture content of 14.3 % (see attached summary of laboratory testing and classification on table below).

Table 1. Summary of Laboratory testing results and soil classification according to TRH14.

TEST PIT	SAMPLE DEPTH (m)	MATERIAL DESCRIPTION	PLASTICITY INDEX	LIQUID LIMIT	% PASSING 0.075mm	LINEAR SHRINKAGE (%)	GRADING MODULUS	PRA CLASS	TRH 14 *
TP 02	0.9– 1.5	Silty clay ;dark brown colluvium	27	58	70	12.5	0.54	A-7-5 (17)	G10
TP 03	0.6-1.5	Yellowish brown, Residual Shale	32	66	63	14.0	0.63	A-7-5 (16)	G10

8.2 Stability of Excavation Sidewalls

All of the borrow pits were observed as having stable sidewalls and this is a good indication for the behaviour of the materials when excavated and allowed to stand vertically, unsupported.

For safety reasons, sidewalls of excavations deeper than 1.5 m should be battered back to 1:1 in dry conditions. Should oblique jointing or any seepage be noted, then the sidewalls may need to be battered at a much flatter gradient. This is only acceptable for excavation depths restricted to less than 3.0 m. All safety precautions should be adhered to.

Should battering be deemed unpractical due to some site conditions, sidewalls should be supported by suitably designed shoring technique.

Adding to the above mentioned failure phenomenon, attention is drawn to some of the factors that can lead to trench sidewall collapse:

- Development of slicken sided surfaces due to drying and wetting.
- Pore water pressure
- Unstable slopes
- Creep from slightly stable slopes left exposed for extended period of time
- Water seepage
- Piping
- Rain
- Additional dead and/or live loads along the side of excavations
- Past weak zone resulting from anthropological activities
- Critical angled weak zones within the strata day-lighting into the excavation.

The failure mechanism could be in the form of:

- Toppling
- Wedge failure
- Plane failure
- Circular failure
- Crumbling

8.3 DCP Tests

DCP tests were not conducted to obtain an indication of the densities and CBR values for the subsoil. Measurements were taken at depths varying from surface to refusal.

8.4 Activity, Expansiveness or Swelling of Soils

Damage to structures erected on potentially active soils occurs where the expansiveness has not been determined and necessary remedial measures not employed. The potential expansiveness of a soil depends upon its clay content, the type of clay mineral present, its chemical composition and mechanical character. A material is potentially expansive if it exhibits the following properties:

- Clay content of more than 12%.
- Plasticity index of more than 12%.
- Liquid limit of more than 30%.
- Linear shrinkage of more than 8%.

The method of van der Merwe (1964) was used to determine the potential heave of soil samples. In addition to van der Merwe's method, the plasticity index and linear shrinkage of soil samples were used to indicate the soils potential expansiveness.

Where development is anticipated on areas with potential expansiveness, the following modified construction methods proposed by Williams et al. (1985) may need to be employed:

- Pre-wetting of expansive soil horizons
- Removal of the active layer
- Construction of moisture barriers and paving around the structures
- Stiffened raft foundations, sandwich raft foundations (two overlying raft foundations with a mattress of gravel or sand between the rafts) or piled foundations.

From the visual observations on site, the potential expansiveness of the soils on the site is Medium to High. This is due to the amount and type of clay and silt content and soil thicknesses along the site. The possibility of structural distress resulting from cyclic drying shrinkage in dry seasons and swell after wetting is therefore limited.

8.5 Geotechnical Constraints

The impact of the geotechnical constraints on housing development can be evaluated according to the Table below, which is a summary of the general geotechnical constraints relevant to urban development (Partridge, Wood & Brink 1993). The class column indicates the severity of the specific constraints for this site.

	CONSTRAINT	SITE CONDITION	CLASS
A	Collapsible soil	Collapsible grain structure absent	1
B	Seepage	Permanent or perched water table is more than 1.5m below ground surface.	1
C	Active Soil	Medium soil heave potential anticipated.	2
D	High Compressibility soil	Low-Medium compressibility expected.	1
E	Erodabilty of soil	Low erodability.	1
F	Difficulty of excavation into 1.5m	None only where there was refusal	1
G	Undermined Ground	No known undermined areas.	1
H	Stability:(Dolomite& Limestone)	No soluble rock encountered therefore the site is stable.	1
I	Steep slopes	Few steep slopes on site.	2
J	Areas of unstable natural slopes	Site is low risk.	1
K	Areas subject to seismic activity	10% probability of an event less than $100cm/s^2$ in 50 years.	1
L	Areas subject to flooding	stream present adjacent to site.	2
Geotechnical Classes: Most Favourable(1);Intermediate(2);Least Favourable(3).			

9. Recommendations

9.1. Foundation design

The geotechnical investigation was carried on the foundation foot prints of the proposed resort, chalets, administration block, cultural village & multi-purpose centre to be built at Molote Village, Boons, North West. It should be borne in mind that the geotechnical boundaries are inferred. So, some variations to the reported conditions should be expected.

The site predominantly falls within NHBRC Site Soil **Class R, H1-H2** (up to 30 mm estimated total settlements) and the proposed structure should be founded on **Normal Reinforced Strip Footing or Raft Foundation**.

Normal Reinforced Strip Footing foundation is therefore recommended that In-situ reconstruction or ripping be done at an average depth of 1.6-2.0 m below surface on consolidated soil or rock. Proper compaction should be adhered to while back filling the trenches and foundations with G5 material and should be compacted to 95% MODAASHTO at 150mm interval.

Due to the high content of clay on site and very low soaked CBR, the designer may also opt to use **Raft foundation** so as to avoid disturbing the clay thereby minimizing the chances of swelling or settling. In-situ reconstruction or ripping is to be done at an average depth of 0.5m.

Road Recommendation: The reasonable assumption for future traffic is: Low-order mixed pedestrian and vehicle route, with a total traffic loading of <0.3 x 106 E80s per lane. (TRH4)

The following recommendations were made:

- In-situ reconstruction or ripping and compacting G9 Material sub-grade to 90% MOD AASHTO density.
- 150mm G2 Base compacted to 88% MOD AASHTO density.
- 300mm G5 sub-base compacted to 95% MOD AASHTO density.
- 40 mm Asphalt overlay with a double seal surface.

Field assessment results shows that ground condition gradually improve in strength from 1,0 m below surface which is a sign of more stable and competent ground condition for the recommended foundation design.

Site drainage should be design in such a way that water is channeled from Buildings into a suitable storm water drainage system to avoid structural distress over a period of time.

A damp proof membrane should be placed in order to prevent the ground water from infiltrating. Such an impermeable layer would assist as a sealing layer.

The foundation solution implemented for this site is satisfactory. No major settlement or differential settlement cracks are foreseen provided the pressures are kept under 50 Kpa.

Conditions prevailing at the site suggest that no problems are foreseen for the development of the proposed structures, provided the recommendations outlined in the report are adhered to.

General

The comments and recommendations contained within this report are based on the exposed sections of the test pit areas and the surrounding rock outcrops.

During exploitation, excavations should be inspected by a geotechnical engineer or engineering geologist to verify that the conditions on site are not at variance with those described in this report. Furthermore, these competent persons should occasionally inspect the sidewalls for safety and stability reasons.

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APPENDIX A

Soil Profiles

Laboratory Results

APPENDIX B

Fig 1 & 1b. Site layout drawing